

APPLICATION FOR UNITED STATES PATENT

FOR

DOWNLOCKING AND/OR UPGRADING INTEGRATED CIRCUIT

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TECHNICAL FIELD & BACKGROUND

The present invention is related to the field of integrated circuit. More specifically, various aspects of the present invention are related to distribution
5 and upgrade of integrated circuits.

Advances in integrated circuit (IC) technology have led to significant increases in the operational frequencies of IC. Typically, a manufacturer of an IC designs and guarantees the IC to operate properly up to a specification maximum operational frequency, if voltage supplied to the IC is within a targeted
10 voltage range. Generally, to reduce power consumption, it is desirable to operate the IC near the lower end of the targeted voltage range.

In addition to being dependent on the applied voltage, the operational frequency of an IC may also be dependent at least in part on the temperature of the IC, the age of the IC, and/or other factors. Thus, various environmental
15 limits, such as, but not limited to, temperature, voltage and so forth, are specified to facilitate a system designer to manage the usage of the IC, to ensure it functions properly. These environmental limits are typically conservatively specified (guardbanded) to accommodate among other things, aging of the IC. The level of conservatism (or magnitude of the guardband) varies from
20 manufacturer to manufacturer, depending in part on the quality experience of the manufacturer.

Additionally, there are often different price-performance points a type of IC (e.g. microprocessor) needs to meet, further complicating the manufacturing and distribution of IC.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be described by way of exemplary
embodiments, but not limitations, illustrated in the accompanying drawings in
5 which like references denote similar elements, and in which:

Figure 1 illustrates a block diagram of an integrated circuit, in accordance
with one embodiment of the present invention;

Figure 2 illustrates the monitor of the voltage regulator controller **Fig. 1** in
further detail, in accordance with one embodiment;

10 **Figure 3** illustrates the monitor of the voltage regulator controller of **Fig. 1**
in further detail, in accordance with another embodiment;

Figure 4 illustrates a system having the IC of **Fig. 1** in accordance with
one embodiment;

Figure 5 illustrates a distribution method for the IC of **Fig. 1**, in
15 accordance with one embodiment;

Figure 6 illustrates a networking environment suitable for practicing a
complementary upgrade method for the IC of **Fig. 1**, in accordance with one
embodiment; and

Figure 7 illustrates the protocol of the complementary upgrade method, in
20 accordance with one embodiment.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

Embodiments of the present invention include, but are not limited to, an IC having operational circuits and a proxy circuit to output a periodic signal (proxy
5 signal) at a frequency (proxy frequency) reflective of a potential the operational frequency of the operational circuits, a voltage regulator controller integrated or associated with the IC to regulate voltage applied to the IC based at least in part on the proxy signal provided by the proxy circuit, and a system having such an IC. Embodiments of the present invention further include methods for distributing
10 and field upgrading the IC, client and system devices to practice the methods.

Various aspects of the illustrative embodiments will be described using terms commonly employed by those skilled in the art to convey the substance of their work to others skilled in the art. However, it will be apparent to those skilled in the art that the present invention may be practiced with only some of the
15 described aspects. For purposes of explanation, specific numbers, materials and configurations are set forth in order to provide a thorough understanding of the illustrative embodiments. However, it will be apparent to one skilled in the art that the present invention may be practiced without the specific details. In other instances, well-known features are omitted or simplified in order not to obscure
20 the illustrative embodiments.

Various operations will be described as multiple discrete operations, in turn, in a manner that is most helpful in understanding the present invention, however, the order of description should not be construed as to imply that these operations are necessarily order dependent. In particular, these operations need
25 not be performed in the order of presentation.

The phrase "in one embodiment" is used repeatedly. The phrase generally does not refer to the same embodiment, however, it may. The terms "comprising", "having" and "including" are synonymous, unless the context dictates otherwise.

5 Referring now to **Fig. 1**, wherein a block diagram view of an IC in accordance with one embodiment, is shown. As illustrated, IC **100** receives its current supply from voltage/current source **110**. IC **100** includes a number of operational circuits (not shown). Further, IC **100** advantageously includes proxy circuit **102** (which also draws current from the same source **110**). For the
10 illustrated embodiment, IC **100** also includes control parameter storage **106** and light weight voltage regulator controller **112**. The illustrated elements are coupled to each as shown.

Operational circuits are employed to provide the functions IC **100** is designed to offer. The functions, and therefore, operational circuits are
15 application dependent, and the application may be of any kind. In one embodiment, IC **100** implements a general purpose microprocessor. In other embodiments, IC **100** may be a graphics processor, a network processor, other application specific integrated circuits (ASIC), or a reconfigurable integrated circuit, such as, but not limited to, Field Programmable Gate Array (FPGA) and
20 so forth.

Proxy circuit **102** is employed to generate a periodic signal (proxy signal) at a frequency (proxy frequency) that is reflective of a potential of the operational frequency of an operational portion of IC **100** of interest (hereinafter, the constituent operational circuit). Recall that the operational frequency is
25 dependent at least in part on the voltage applied, the temperature, and the age of an IC, accordingly, in various embodiments, proxy circuit **102** may be formed at a

location of the IC that is near the constituent operational circuit, which operational frequency potential is to be reflected. Such proximal placement allows proxy circuit **102** to substantially experience the same process variations in its formation, as well as ambient influences during operation, as the constituent
5 operational circuit which operational frequency it is to reflect. However, in other applications, for other reasons, proxy circuit **102** need not be so proximally placed.

In various embodiments, proxy circuit **102** is a ring oscillator, which on application of power, continuously generates a periodic signal (proxy signal) at a
10 frequency (proxy frequency). The oscillator toggles per unit time is a measure of frequency. The number of stages or the length of the ring oscillator is implementation dependent. In particular, it may be dependent on the manner the oscillator's frequency is measured. In alternate embodiments, other periodic signal generation circuits may be employed. Further, it is anticipated that in
15 some embodiments, proxy circuit **112** may have configurable elements, to allow customization of the characteristics of the proxy signal.

Light weight voltage regulator controller **112** is employed to conditionally regulate the voltage applied to IC **100** by source **110**, based at least in part on the potential of the operational frequency of all or a subset of the operational
20 circuit(s) of IC **100**, as reflected by the proxy frequency of the proxy signal. For the illustrated embodiment, voltage regulator controller **112** includes monitor **104** and control block **108**, coupled to each other as shown. Voltage regulator controller **112** is referred to as light weight, because for the intended usage, it is not necessary for voltage regulator controller **112** to include elements, such as
25 inductors, bulk caps, and so forth.

For the embodiment, monitor **104** is employed to detect the difference between the proxy frequency and a target of the proxy frequency. The target of the proxy frequency is typically determined at manufacturing time, or more specifically, quality testing time, when the specification maximum of the operational frequency of the constituent operational circuit is determined. The specification maximum of the operational frequency of the constituent operational circuit at a particular temperature, may be determined e.g. through a binary search, while IC **100** is held at the particular temperature. The search may also be conducted employing a voltage reference. Typically, the searches are conducted for a number of temperatures in a temperature range. Other methods may also be employed to determine the specification maximum of the operational frequency. Couple of embodiments of monitor **104** will be described later, referencing **Fig. 2-3**.

As will be readily apparent from the descriptions to follow, in alternate embodiments, the responsibilities of monitor **104** may be more or less. That is, in these alternate embodiments, some of the responsibilities of monitor **104** may be “pushed out” to control block **108**, or vice versa. That is, the demarcation between monitor **104** and control block **106** is partially arbitrarily, and implementation dependent.

For the embodiment, control block **108** is employed to generate control signals for source **110**, based at least in part on the outputs of monitor **104**. In various embodiments, the control signals control the pulse widths of various transistors employed by source **110** in generating current for IC **100**.

In general, control block **108** is employed to generate control signals to decrease the voltage applied to IC **100** if the potential of the operational frequency of the constituent operational portion of IC **100** is believed to be higher

than its target operational frequency, and to generate control signals to increase the voltage applied to IC **100** if the potential of the operational frequency of the constituent operational portion of IC **100** is believed to be lower than its target operational frequency.

5 Further, the amount of increase/decrease is in general a function of the amount of difference detected for the proxy frequency and its target (which may be selected based on a target maximum operational frequency for the constituent operational circuit). However, other factors, such as temperature of IC **100**, age of IC **100**, as well as precision desired (i.e. granularity of control), may be taken
10 into consideration, in generating the control signals to increase or decrease the voltage and/or current applied. The functional relationship between the adjustment to be undertaken and the factors to be considered, may be linear or non-linear, depending substantially on the design and usage characteristics of IC **100**, and it is typically, though not necessarily, empirically determined.

15 In various embodiments, depending on the sophistication of the models, and therefore, the complexity of the "calculations" required to generate the control signals, control block **108** may be implemented with a relatively simple to a relatively complex circuit, including, but not limited to, a collection of gates configured with combinatorial logic, or a general purpose microcontroller
20 programmed with control logic.

For the embodiment, control parameter storage **106** is employed to store various control parameters. In particular, for the embodiment, it is employed to store the target proxy frequency of the constituent operational portion of IC **100**, and various control values to control the operation of voltage regulator controller
25 **112**, in particular, monitor **104**. In various embodiments, the stored control parameters may also include an upward adjustment as well as a downward

adjustment to the target proxy frequency of the proxy circuit, to be described more fully below.

In various embodiments, control parameter storage **106** may be implemented employing non-volatile storage, such as read-only-memory (ROM),
5 electrically erasable ROM (EEPROM), flash memory, and so forth, and/or fuses, i.e., a combination thereof. In other embodiments, control parameter storage **106** may also be implemented employing volatile storage, such as random access memory (RAM) if facilities to save to, and restore from a persistent store of a host device hosting IC **100** are also provided.

10 Source **110** typically includes a number of transistors, diodes, inductors, capacitors and/or resistors coupled to one another to provide a voltage/current output. Source **110** may be a voltage/current supply of any kind, as long as it is able to meet the voltage and/or current requirement of IC **100**, and includes an interface to allow its output voltage to be controlled by control block **108** by
15 controlling e.g. one or more of its transistors.

Resultantly, by virtue of the ability to reliably estimate the operational frequency potential achievable by the operational circuits, and adjust the voltage applied to IC **100** accordingly, it is expected that the specification maximum operational frequency may be achieved with voltage near the lower end of the
20 design voltage range. Thus, it is expected that the specification maximum operational frequency is likely to increase, but at the same time, there will be substantial power savings.

Further, in various embodiments, control parameter storage **106** may also be employed to store various environmental limits to be monitored and managed,
25 to ensure the proper operation of IC **100**. Examples of environmental limits include, but are not limited to various critical temperature limits, nominal

maximum operational frequency, minimum and maximum voltage, and so forth.

These environmental limits are employed by light weight voltage regulator controller **112** and/or various off-chip system management facilities to manage the operation of a host system, of which IC **100** is a component. From the

5 description to follow, it will be appreciated by those of ordinary skill in the art, that by virtue of the novel features and methods of the present invention, typically, these environmental limits may be set more aggressively to "lower" limits. It is expected that employment of various embodiments of the present invention will likely lead to significant reduction in all or selected ones of the typical
10 environmental limits.

Additionally, IC **100** may also include a special mode of operation for the above described calibration and determination of the specification maximum operational frequency (including the target for the proxy frequency), and a number of environmental factor sensors or circuits, such as, but not limited to,
15 voltage sensors, temperature sensors, and so forth, as well as an input terminal for the provision of voltage references, to facilitate the calibration and determination.

While for ease of understanding, voltage regulator controller **112** (with monitor **104** and control block **108**) and control parameter storage **106** are being
20 illustrated as part of IC **100**, in alternate embodiments, one or more of these elements or sub-elements may be located off chip, on e.g. a circuit board, to which IC **100** is mounted.

Further, while also for ease of understanding, only one proxy circuit **102** is shown, in alternate embodiment, IC **100** may employ multiple proxy circuits **102**,
25 one each for different constituent regions. For these embodiments, voltage regulator controller **112** (with monitor **104** and control block **108**) and control

parameter storage **106** may be modified to cooperate with the multiple proxy circuits **102** (e.g. interleavingly), or multiple sets of these resources, one for each proxy circuit **102** may be provided instead.

Figure 2 illustrates monitor **104** of voltage regulator controller **112** of **Fig. 1** in further detail, in accordance with one embodiment. As illustrated, for the embodiment, monitor **104** includes counters **202-204**, divider **206**, synchronizer **208**, register **210**, and comparator **212**, coupled to each other, proxy circuit **102**, and control parameter storage **106** as shown.

Comparator **212** is employed to receive the determined proxy frequency, i.e. frequency of the proxy signal outputted by proxy circuit **102**, (from register **210**), and a target of the proxy frequency (from control parameter storage **106**), and in response, generates an output indicating the difference between the two frequencies.

Counter **204** is employed to sample the proxy signal for a period of time, or more specifically, for the embodiment, a derived version of the proxy signal **213**, to determine the frequency of the proxy signal, which as described earlier, is considered reflective of a potential of the operational frequency of the constituent operational circuit(s) of IC **100**. Counter **204** includes in particular an input terminal to receive the derived version of the proxy signal **223**, which is aligned with the operational cycles of the constituent operational circuit(s), to be described more fully below. Counter **204** further includes a "clear" (CLR) input terminal to receive control signal **220** to periodically clear it, to effectively control the start and stop of sampling (counting) for each time period. Counter **204** further outputs the determined proxy frequency for register **210**.

Register **210** is employed to store the determined proxy frequency. Register **210** includes an input terminal to allow the same control signal **220** to be

provided to control register **210** to latch the determined proxy frequency outputted by counter **204** at the end of a sampling period, synchronous to the time when counter **204** is being cleared to start sampling for a new time period, and to output a stored determined proxy frequency for comparator **212**.

5 For the embodiment, divider **206** is employed to divide the periodic signal received from proxy circuit **102** to generate a derived version of the periodic signal **221**. Typically, this derived version of the periodic signal **221** is not aligned with the operational cycles of the constituent operational circuit(s) of IC **100**.

10 The terms "alignment" or "aligned" as used herein in the specification, and in the claims, refer to edges of the signal pulses being aligned, i.e. they substantially rise and fall together (in phase or phase shifted), but not necessary of the same frequencies. For example, for the purpose of this specification and the claims, a signal with a 200MHz frequency and a signal with a 100MHZ are
15 considered aligned, if the edges of the pulses of the slower 100MHZ signal substantially rise and fall with every other edges of the pulses of the twice as fast 200MHZ signal (in phase or phase shifted).

 Synchronizer **208** is employed to align the derived version of the proxy signal **221** with the operational cycles of the constituent operational circuit(s) of
20 IC **100**, and output the aligned version as derived version **223** to counter **204**. Thus, synchronizer **208** receives the derived version **221** from divider **206**, and clock signal (CLK) **224** as inputs. CLK **224** is a clock signal with a frequency that is either the same or a multiple of the frequency of the clock signal employed to drive the constituent operational circuit(s) (in phase or phase shifted). In other
25 words, as an example, if a clock signal with a 800MHz frequency is employed to generate a clock signal of 400MHZ for the constituent operational circuit(s), CLK

224 may be a clock signal with a frequency of either 800 MHZ or 400 MHZ (in phase or phase shifted).

Counter **202** is employed to generate control signal **222**. Counter **202** receives the same clock signal CLK as input, and counts accordingly. Counter **202**
5 outputs its count as control signal **222**.

While the embodiment of **Fig. 2** employs counter **204** to determine the frequency of the proxy periodic signal outputted by proxy circuit **102**, in alternate embodiments, the frequency of the proxy periodic signal may be determined via other approaches. For example, an implementation with proxy circuit **102** having
10 an m stage oscillator, and counter **204** counting up to n cycles, may also be implemented with proxy circuit **102** having m x n stages, with the proxy frequency being determined based on the amount of delay incurred by a signal traversing through the m x n stages.

Figure 3 illustrates monitor **104** of **Fig. 1** in further detail, in accordance
15 with another embodiment. The embodiment of **Figure 3** is substantially the same as the embodiment earlier described referencing **Fig. 2**, except that comparator **212** is enhanced to also receive one or more adjustments to the target of the proxy frequency to be taken into consideration when generating the difference between the determined proxy frequency and its target.

20 In various embodiments, the adjustments include an upward adjustment and a downward adjustment. The adjustments provide a manufacturer of IC **100** with a number of flexibilities in marketing the IC. For example, the upward adjustment may be employed to market IC **100** as a part with a lower specification maximum operational frequency, even though during production, it
25 was tested and confirmed to be capable of operating reliably with a higher unadjusted specification maximum operational frequency. Presumably, IC **100**

will be marketed with a downward price adjustment when compared to other IC marketed for operation with the higher unadjusted specification maximum operational frequency. However, subsequently, the downward adjustments may be employed to field upgrade IC **100** to operate with a higher specification maximum operational frequency, which could be as high as the original higher unadjusted specification maximum operational frequency or lower (reflecting the part's age), depending e.g. on the amount of an upgrade payment received. This is just one of many possible applications of the various embodiments of the present invention.

10 In alternate embodiments, comparator **212** may be merely enhanced to accept only one adjustment to the target proxy frequency. In other words, the adjustments are all summed into a net adjustment, before it is provided to comparator **212**.

Note that for the same reason, the earlier described application may be practiced with the embodiment of **Fig. 2** if all adjustments are factored into the target proxy frequency before it is provided to comparator **212**.

In other words, similar to the earlier description of the demarcation between monitor **104** and control block **108** need not be as described, and may move in either direction with monitor **104** assuming some of the functions of control block **108** or vice versa, likewise, the demarcation between control parameter storage **106** and monitor **104** need not be as described either, and may move in either direction with control parameter storage **106** assuming some of the functions of monitor **104** (in particular, comparator **212**), or vice versa.

Figure 4 illustrates a system in accordance with one embodiment. As illustrated, for the embodiment, system **400** includes microprocessor **402**, memory **404**, and networking interface **406** coupled to each other, via bus **408**.

For the embodiment, microprocessor **402** is advantageously equipped with proxy circuit **102**, voltage regulator controller **112** (with monitor **104** and control block **108**) and control parameter storage **106**, as early described for IC **100**.

Accordingly, the voltage applied to microprocessor **402** may be adjusted in view
5 of the operational frequency microprocessor **402** is believed to be capable of, based on the experience of proxy circuit **102**.

Beside the advantageous incorporation of elements **102**, **106** and **112**, microprocessor **402**, memory **404**, networking interface **406** and bus **408** all represent corresponding broad ranges of these elements known in the art or to
10 be designed. Further, as described earlier, in alternate embodiments, all or portions of voltage regulator controller **112** may be disposed outside microprocessor **402**.

Depending on the applications, system **400** may include other components, including but are not limited to non-volatile memory, mass storage
15 (such as hard disk, compact disk (CD), digital versatile disk (DVD) and so forth), graphical or mathematic co-processors, and so forth.

In various embodiments, system **400** may be a personal digital assistant (PDA), a wireless mobile phone, a tablet computing device, a laptop computing device, a desktop computing device, a set-top box, an entertainment control unit,
20 a digital camera, a digital video recorder, a CD player, a DVD player, or other digital device of the like.

Further, in various applications, system **400** may have multiple microprocessors having integrated or associated voltage regulator controllers as earlier described. Moreover, the multiple microprocessors may be multiple
25 processor cores integrated on the same die.

Figure 5 illustrates a distribution method for the IC of **Fig. 1**, in accordance with one embodiment. The method provides a manufacturer with another approach that can be used in lieu of or in addition to the different functional integration approach (e.g. with or without on-chip cache in the case of a microprocessor) to meet different price-performance points. The approach has the potential advantage of enabling a manufacturer to offer different price-performance points in a more cost efficient manner.

For ease of understanding, the distribution method will be described in the context of an IC having one proxy circuit, and the proxy frequency of the proxy signal outputted by the proxy circuit is reflective of the potential of the operational frequency of the operational circuit of the IC. However, it is well within the ability of those of ordinary skill in the art to modify and extend the method to cover situations where the proxy frequency of the proxy signal is merely reflective of the potential of the operational frequency of a constituent portion of the IC, and/or the IC having more than one proxy circuit.

As illustrated, upon fabrication, a target for the proxy frequency of the proxy signal is determined for each IC, **op 502**. In various embodiments, the target for the proxy frequency is determined in conjunction with nominally assigning a specification maximum operational frequency to the IC. The term “nominal” refers to the fact that under the novel method, the specification maximum operational frequency of an IC may be reassigned at distribution time, to be described more fully below.

Recall that specification maximum operational frequency is the fastest operational frequency a manufacturer would guarantee proper operation for the IC for a voltage range. Due to process variations and other factors, the fastest operational frequency a manufacturer would guarantee for a voltage range varies

from IC to IC, even if they are of the same design, and manufactured by the same process. Typically, a manufacturer offers the ICs with different specification maximum operational frequencies as different price-performance bins.

5 In various embodiments, the nominal assignment is guided by the fastest operational frequency the IC is deemed to be able to reliably achieve. This fastest operational frequency the IC can reliably achieved is determined by testing the IC under various temperature and voltage conditions, and observe the operational frequencies reliably achieved under the various testing conditions, in
10 particular, the voltage ranges these operational frequencies can be reliably achieved.

Conventionally, once assigned, an IC is seldom reassigned with another specification maximum operational frequency, unless it is for correcting an incorrect assignment. Concurrently, as described earlier, a number of guardband
15 limits for temperature, voltage, and so forth would be conservatively selected for a system designer to manage and ensure the reliable performance of the IC. Again, the degree of conservatism varies from manufacturer to manufacturer, typically, dependent on the manufacturer's own quality experience.

However, as described, for the novel distribution method, the determined
20 specification maximum operational frequency is only nominally assigned. Further, by virtue of the fact that the voltage applied to the IC is regulated based at least in part on the difference between the proxy frequency of the proxy signal and its target, the guardband limits may be set less conservatively (for a given quality history).

25 During the testing, the proxy frequency of the proxy signal is noted for each fastest operational frequency reliably achieved under a testing condition.

The proxy frequency of the proxy signal corresponding to the reliably achieved fastest operational frequency used as a guide in assigning the specification maximum operational frequency, is selected as the target for the proxy frequency.

5 In various embodiments, in particular, those with voltage regulator controller **112** integrated as part of the IC, the IC is configured with the selected target proxy frequency, **op 504**. In other embodiments, where the voltage regulator controller **112** is not integrated as part of the IC, and is disposed on e.g. a system board on which the IC is attached, the target proxy frequency
10 information may be distributed to the system manufacturer for configuration instead.

Subsequently, for various reasons, including but are not limited to a price-performance point (typically a lower price-performance point) having a shortage of parts due to e.g. unexpected higher demand, under this novel distribution
15 method, the IC may be re-assigned with the specification maximum operational frequency of the particular price-performance bin instead, **op 506-508**.

Further, the IC is effectively re-configured with the target proxy frequency corresponding to the reliably achievable fastest operational frequency corresponding to the re-assigned specification maximum operational frequency.
20 For an IC with integrated voltage regulator controller **112**, the re-configuration may be effectuated by re-configuring the IC with a replacement target proxy frequency or an adjustment to it, **op 508**. Likewise, for IC to be used with voltage regulator controller **112** being disposed on a system board, the replacement target or adjustment information may be distributed to the system manufacturer
25 to perform the configuration instead. This process, resulting in an IC being re-

assigned to a lower price-performance bin, is also referred to as a downlocking process.

In various embodiments, in addition to or in lieu of the target of the proxy frequency, a number of other control variables, including but are not limited to
5 bus-to-core frequency multiplier (of the constituent operational circuit), minimum or maximum Vcc, maximum temperature, bus frequency ratio multiplier, and so forth, may be downlocked.

Figure 6 illustrates a network embodiment suitable for practicing a complementary upgrade method for the IC of **Fig. 1**, in accordance with one
10 embodiment. As illustrated, network environment **600** includes client device **602** and server device **604** coupled to each other via network **606**.

Both client device **602** and server device **604** include appropriate networking interfaces **616** and **626**, and device drivers (not shown) for communicating with each over network **606** in accordance with a mutually
15 supported communication protocol, e.g. Transmission Control Protocol/Internet Protocol (TCP/IP). In various embodiments, network **606** includes the Internet.

For the illustrated embodiment, client device **602** further includes IC **100** in the form of a microprocessor, coupled to networking interface **616**, and storage **614** coupled to IC **100** having programming instructions **618** designed to enable
20 client device **602** to practice its part of the upgrade protocol.

Similarly, server device **604** further includes one or more processors **622**, coupled to networking interface **626**, and storage **624a** coupled to processor(s) **612** having programming instructions **628** designed to enable server device **604** to practice its part of the upgrade protocol. For the embodiment, server device
25 **624** also includes storage **624b** having IC part upgrade information database stored therein.

In alternate embodiments, in lieu of IC **100** being a microprocessor, IC **100** may be other types of IC, and client device **602** includes another microprocessor to practice the client aspect of the upgrade protocol. In yet other embodiments, client device **602** may be practicing the client aspect of the upgrade protocol on
5 behalf of another client device having IC **100**, i.e. IC **100** is not disposed in the client device practicing the client aspect of the upgrade protocol.

Figure 7 illustrates the protocol between the client device and the server device of **Fig. 6** in further detail, in accordance with one embodiment. As illustrated, the protocol starts with client device **602** and server device **604**
10 establishing a connection with each other, **702-704**. As described earlier, the connection may be of any type, including but are not limited to a TCP/IP connection.

After establishment of the connection, client device **602** in due course requests server device **604** for the upgrade data, **706**. In response, for the
15 embodiment, server device **604** requests client device **602** to provide identification information for the IC **100** to be upgraded, **708**. In turn, client device **602** provides the requested identification information, **710**.

In various embodiments, the identification information may be a serial number of the IC **100** which can lead to the identification of the product family, stepping, and/or the target proxy frequency associated. Alternatively, one or
20 more of the information may be explicitly provided by client device **602** to server device **604**. Further, in alternate embodiments, the identification information may be provided as part of the initial upgrade request.

These and other subsequent exchanges of information between client
25 device **602** and server device **604** may be performed employing any one of a

number of messaging protocols, including but are not limited to the HyperText Transmission Protocol (HTTP).

After receipt of the relevant identification information of IC **100** (directly or indirectly), service device **604** determines if an upgrade is available, **712**.

- 5 Service device **604** then notifies client device **602** of the result of the determination accordingly, i.e. whether an upgrade is available, **714**. Typically, if an upgrade is available, payment for the upgrade is requested.

- The determination may be performed by accessing, e.g. an upgrade database, locally located with server device **604**, or on a remote storage. The
10 upgrade database may be organized employing any one of a number of data organization techniques. Similarly, the retrieval may be effectuated employed any one of a number of data access techniques.

- Assuming IC **100** may be upgraded, and client device **602** is so notified with a request for payment. Next, client device **602** may effectuate tender of
15 payment, **716**. The payment may be effectuated employing any one of a number of electronic payment techniques, directly to server device **604** or indirectly through a financial services third party. Further, the term "payment" as used herein includes monetary as well as non-monetary considerations, e.g. coupon.

- After receipt of payment, service device **604** provides the upgrade data to
20 client device **602**, **718**. As described earlier, the upgrade data may include a replacement target proxy frequency, a replacement adjustment for the associated target proxy frequency, or an additional adjustment to be applied to the associated target proxy frequency. In various embodiments, in addition to or in lieu of the target of the proxy frequency, the upgrade data may include
25 replacement or adjustment to bus-to-core frequency multiplier (of the constituent operational circuit), minimum or maximum Vcc, maximum temperature, bus

frequency ratio multiplier, and so forth. In other embodiments where the control logic for generating the control signals to regulate the voltage applied to the IC is implemented via microcode, the upgrade data may also include replacement of or modification to the microcode. The upgrade process is also referred to as an
5 undownlocking process.

Further, the upgrade data may be provided in an encrypted form, employing any one of a number of encryption/decryption techniques.

After receipt (and if applicable, recovery) of the upgrade data, client device
602 causes IC 100 to be upgraded, 720, by effectively associating IC 100 with
10 the upgraded target proxy frequency and/or one or more of the above described control variables and voltage regulation microcode, by configuring IC 100 or its host system board with the upgrade data.

Thereafter, during operation, regulation of voltage to be applied to IC 100 is based in part on the upgraded target proxy frequency instead.

15 Conclusion and Epilogue

Thus, it can be seen from the above descriptions, a novel integrated circuit distribution method, a novel complementary upgrade method, systems equipped to practice various aspects of the methods, have been described. While the present invention has been described in terms of the foregoing embodiments,
20 those skilled in the art will recognize that the invention is not limited to the embodiments described. The present invention can be practiced with modification and alteration within the spirit and scope of the appended claims. The description is thus to be regarded as illustrative instead of restrictive on the present invention.